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Review Article

Effects of Dentally and Skeletally Anchored Forsus Fatigue Resistant Device on the Craniofacial Complex - A Review Correlating Clinical and Finite Element Studies

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Abstract

The challenge in Class II malocclusion is to achieve a maximum skeletal correction by utilizing residual growth which is possible by growth modification procedures. These procedures utilize a functional appliance which can be either removable or fixed, rigid or hybrid. Among hybrid fixed functional appliances Forsus Fatigue Resistant Device (FFRD) has been used popularly in non-compliant adolescent patients to correct the sagittal discrepancy. Many Clinical and Finite Element studies have been performed to assess the effects of dentally and skeletally anchored Forsus FRD on the craniofacial complex.

Keywords: Skeletal Class II Malocclusion; Growth Modification; Functional Appliance; Forsus Fatigue Resistant Device (FFRD); Dentally Anchored; Skeletally Anchored

Abbreviations

FFRD: Forsus Fatigue Resistant Device; FEM: Finite Element Analysis; VTO: Visual Treatment Objective; TMJ: Temporomandibular Joint; FMA: Frankfurt Mandibular plane Angle; IMPA: Incisor Mandibular plane Angle; Co-Gn: Condylion-Gonion; ANS: Anterior Nasal Spine; Me: Menton

Introduction

Mandibular retrognathism is a cardinal factor contributing to skeletal class II malocclusion affecting one-third of the population rather than maxillary prognathism [1-3]. Treatment strategy for the management of retrognathic mandible mainly depends on the age, growth potential, severity of malocclusion, location of a discrepancy, and compliance of the patient [4,5]. Mandibular retrognathism shows no tendency for self-correction with growth and worsens during the pubertal growth spurt.

Growth modification procedures executed during mixed or early permanent dentition before the suspension of active growth can induce more skeletal and fewer dental changes [6]. On the contrary, for individuals who are at the edge of the pubertal growth spurt, there would be more dental changes and fewer skeletal changes. Whereas after growth termination, it is not possible to undertake growth modification procedures. In such circumstances, the skeletal discrepancy can be camouflaged by orthodontic tooth movement or orthognathic surgery [7,8].

For the foregoing reasons, mandibular advancement in growing individuals is best addressed by Functional Appliances which alter the posture of the mandible sagittally and vertically by modifying the neuromuscular environment of the dental and skeletal tissues. It can be removable or fixed; rigid or flexible. Though Removable functional appliances are easy to fabricate and cost-effective, they are robust, troublesome, and compliance reliant which led to the invention of appliances [9].

Fixed functional appliances are used in non-compliant adolescent patients who have passed their maximum pubertal growth spurt. They work round the clock utilizing the residual growth to invoke rapid sagittal correction in a short span. One of the most preferred compliance-free fixed functional appliances is Forsus Fatigue Resistant Device (FFRD,3M Unitek, Monrovia, Calif) [10]. If dentally anchored, they produce undesirable side effects like distal and intrusive movement of maxillary molars, mesial movement of mandibular molars and labial flaring of mandibular incisors which can be curtailed by the skeletally anchored fixed functional appliance with miniscrews or miniplates [11-15]. Studies on miniplate anchored Forsus to the mandible showed decrease in dentoalveolar side effects and increase the remodeling changes in the condylar head and glenoid fossa which was not the case with miniscrew [16]. Further to decrease the maxillary effect and increase the mandibular effect, utilization of bimaxillary skeletal anchorage has been reported in the literature [17]. Furthermore, to measure the clinical effectiveness of the appliance, stress exerted by the appliance on the bone has been studied with FEM [26,31,32].

This article reviews the effects on the craniofacial complex by correlating the clinical and finite element studies on dentally and skeletally anchored Forsus Fatigue Resistant.

Indications

- Skeletal class II pattern with mandibular retrognathia and skeletal class III pattern with retrusive maxilla in adolescent patients who have passed the maximal pubertal growth.
- Low mandibular plane angle cases
- Normal or reduced lower facial height
- Class II dental arch relationship with increased overjet and normal or increased overbite.
- To enhance anchorage.

Contraindications

- If used in nongrowing individuals, the skeletal alterations will be minimal, the treatment effects will be confined to the dentoalveolar area and may lead to TMJ disorder.
- Hyperdivergent facial pattern.
- A patient with negative VTO (visual treatment objective)

Advantages

- Treatment duration is around 6-8months.
- It allows for the lateral movements of the mandible.
- They can be given in mouth breathers who are unable to adapt to removable appliances.
- Does not interfere in speech or mastication.
- Procedures such as rapid maxillary expansion and others can be carried out simultaneously.
- No separate stage of multi-attachment therapy is required, it can be done simultaneously.

Disadvantages

- Risk of development of dual bite with an attendant risk of TMJ dysfunction if treated inadequately.
- Though treatment results can be achieved within 6-8 months, retention of the result has to be maintained using a removable functional appliance.
- Masticatory efficiency is reduced even after the patient gets used to the appliance.
- High incidence of breakage and loosening of the appliance.
- Most of the appliances are expensive or may require good laboratory support.

Appliance design [10]

Forsus Fatigue Resistant Device (FRD,3M Unitek, Monrovia, Calif) is a three-piece, semirigid, telescoping system, incorporating a super-elastic nickel titanium coil spring that produces about 200g of force when fully compressed which is transmitted to the sites of attachment. It was given by an American orthodontist William Vogt of Philadelphia. The appliance comprises of the following parts

- Push rod: Engaging the lower archwire directly or indirectly.
- Superelastic open Niti coil spring assembly.
- Connecting spring assembly to molar is available in four sizes 25, 29, 32, and 35mm and are of two types, L-pin ball end module and EZ Module.

Depending on the attachment Forsus FRD can be Dentally anchored (Figure 1) where it attaches to the maxillary first molar and onto the mandibular archwire, distal to either the canine or first premolar bracket and skeletally anchored (Figure 2) where it attaches to the miniplate in the mandibular symphysis near the canine-premolar region.

Figure 1

Figure 2

Mode of action

Both dentally and skeletally anchored Forsus Fatigue Resistant Device postures the mandible forward similar to the removable functional appliances as it exerts its effects via teeth to the underlying bone by transmitting the forces developed as a result of the continuous forward posturing of the mandible. It is said to cause an increase in the contractile activity of lateral pterygoid muscle which results in the intensification of the retrodiscal pad thereby enhancing the local mediators of inflammation.

This review is discussed under the following

Clinical and Finite element studies of Forsus Fatigue Resistant Device

- Dentally anchored FFRD
- Skeletally anchored FFRD

Effects of dentally anchored Forsus Fatigue Resistant Device

Skeletal effects

Various clinical studies exhibited a greater skeletal effect on the maxillary structures by restraining the sagittal advancement of the maxilla. This can be explained by the decrease in SNA, NA Perp to Pt A, NA ll HP and Co-A values which attribute to the retrusion of the apical base of the maxilla, thus causing the "headgear effect" exerted by the appliance [18-22]. A FEM study by Vineeth., *et al.* demonstrated that the pterygoid plate and maxillary dentition exhibited posterior and superior displacement similar to that seen with the use of headgear [26]. On the contrary, Graham., *et al.* found that the maxilla and mandible moved mesially with the mandible moving more than the maxilla [11] this was not proven by any FEM studies. There is an increase in effective mandibular length (Co-Gn), SNB, Beta, and YEN angles with the use of the Forsus device which positioned the mandible anteriorly [18,20,22]. This can be confirmed with FEM studies where the von Mises stress and the maximum principal stress increased in the cortical bone of mandible and the condyle with the appliance due to constant forward positioning of the mandible with greatest displacement seen in the parasymphyseal and midsymphyseal regions with improvement in the sagittal position of chin. Nevertheless, the study by Doa., *et al.* did not find any increase in SNB angle but the angle of convexity improved due to decrease in SNA [19]. But this effect was not proven by any of the FEM studies

Regarding the changes in vertical skeletal relationships, Franchi., *et al.* suggested that the increase in lower anterior facial height (ANS to Me) was significantly greater in subjects with dentally anchored forsus, whereas Aslan., *et al.* demonstrated only posterior facial height increment [18,12]. On the other hand, Graham., *et al.* reported no significant changes in vertical and angular measurements [11]. Also, there were no significant changes observed in the mean FMA (Frankfort mandibular plane angle) and Gonial angle by Dimitrios., *et al.* whereas Kaur., *et al.* reported a decrease in lower gonial angle [22].

These effects were not depicted in any of the FEM studies.

Dental effects

Various clinical studies showed significant reduction in overjet, overbite, and interincisal angle [20-22]. Franchi and Aras., *et al.* [20,22] observed distal tipping of maxillary molars, whereas, Jones and Doa., *et al*. found no significant maxillary molar intrusion or distal movement instead there was a mesial movement of maxillary molars which was also revealed by Graham., *et al.* [11,19]. He also suggested that the mandibular molars and incisors moved mesially which improved the overjet and also there was extrusion of mandibular first molars [18,19,21-23]. Maxillary incisors were palatally tipped, backwardly placed, and showed a greater vertical eruption [18,20,21]. The mandibular incisors were proclined with a significant increase in IMPA [21,22]. It also exhibited forward movement and intrusion [19,20,23]. This can be confirmed with FEM studies where the von Mises stress and the maximum principal stress increased in the mandibular anterior teeth with the appliance [26].

Soft tissue changes

Soft tissue measurements showed a significantly greater backward movement of the soft tissue A point in the Forsus FRD group [18] with decrease in facial convexity [22]. The nasolabial angle increased, upper lip strain decreased, and better lip competency was observed at the posttreatment stage [21,24]. The change in the nasolabial angle and upper lip strain was attributed to the “maxillary growth restriction and distalisation of maxillary molars” exerted by the push action of Forsus [18]. An increase in chin prominence [19,21] was noted as a result of significant increase in the mean distances of skeletal and soft tissue Pog from pre-treatment [21]. These changes cannot be depicted through FEM studies.

Effects of skeletally anchored Forsus Fatigue Resistant Device

Skeletal effects

According to few clinical studies Miniscrew anchored Forsus device was found to be effective in the elimination of lower incisor protrusion [12,13] but had no significant effect on maxilla and mandible in sagittal position. Thus, the changes were dentoalveolar and seemed unsuccessful in correcting the skeletal discrepancy. Melvut., *et al.* were the first to use a mini plate anchored Forsus device to the mandible which exhibited skeletal changes [15]. According to them, this design produced a significant skeletal change by restraining the maxillary growth and accelerating mandibular growth. These were followed by studies which reported similar findings [16,25].

Kochar., *et al.* [17] used bimaxillary skeletal anchorage and observed significant restrain maxilla along the vertical plane (high pull headgear effect) and significant increase in the effective mandibular length and mandibular vertical position [27]. This increase in the effective mandibular length was attributed to the adaptational growth in the mandibular condyle due to stable anchorage unit [18,19,25,28]. This can be confirmed by the FEM study by Patil., *et al.* which revealed Von Mises and principal Stress were maximum in the mandibular cortical bone section in the canine region at the bone and miniplate interface, and minimum stress was found in the periodontal ligament [32].

Though the above-mentioned studies revealed significant change in the mandibular sagittal position, few studies report contrast findings, that Forsus FRD has little or no skeletal effect on mandibular growth [12-14]. The reason may be related to resistance of miniscrews to the forward force direction of the forsus device. Also, a 6-month treatment period may be insufficient to stimulate mandibular growth [12].

Total anterior facial height, lower anterior facial height, and posterior facial height increased with miniplate anchored forsus device [12,13,15,25]. This is because the new forward position enhances condylar growth vertically and increases both posterior and anterior face height. However, Oztoprak., *et al.* and Kochar., *et al*. reported no significant change in the anterior or posterior face heights [17,29]. These effects were not depicted in any of the FEM studies.

Mandible showed posterior rotation with miniplate anchored Forsus [15,25,27,28]. In contrast, Aslan., *et al.* and Osama., *et al*. reported non-significant changes in the mandibular plane angle with miniscrew-supported Forsus device [12,13,25].

As for the transverse plane, maxillary and mandibular widths did not show statistically significant differences [15].

Dental effects

The effect on maxillary molar was intrusion and distal movement of maxillary dentition due to increased anchorage of the mandibular dentition by miniscrews and miniplates [13,15,25,30]. The mandibular molars were extruded with mesial movement and tipping [15,28]. On the contrary, Aslan., *et al.* found no mesial movement and tipping of mandibular molars [12].

The maxillary incisors retruded, extruded and retroclined. The retroclination was greater compared to the dentally anchored

Forsus device. These findings were similar to the previous Forsus studies indicating that extrusion and retrusion of the maxillary incisors are inevitable side effects of Forsus appliances [13,15,18,25,28,30]. No significant dentoalveolar changes were observed on maxillary dentition when bimaxillary skeletal anchorage was used [17].

Proclination of mandibular incisors was effectively minimized with the use of miniscrews, but Osama., *et al.* suggested that miniscrew-anchored FRD couldn't limit mandibular incisor protrusion [12,13]. Kochar., *et al.* used bimaxillary anchorage and suggested that incorporation of mini implants with Forsus FRD reduced the mandibular incisor proclination [17]. This can be confirmed by FEM study by Patil., *et al.* where the minimum stress was experienced at the dentoalveolar structures compared to the skeletal structures. Aslan., *et al.* reported intrusion of lower incisors but on the contrary Elkordy., *et al.* reported mandibular incisor extrusion [12,28].

Soft tissue changes

Similar changes were shown with skeletally anchored Forsus FRD. Various clinical studies showed significant retrusion of the upper lip [13,25]. The lower lip and soft tissue pogonion significantly moved forward. These changes improved the facial soft tissue convexity. These changes cannot be depicted through FEM studies.

Clinical studies		
Effects	**Dentally anchored FFRD**	**Skeletally anchored FFRD**
Skeletal	Head-gear effect in the maxilla Little Increase effective mandibular length Increased in lower anterior facial height	Head-gear effect in maxilla Little Increase effective mandibular length Increased in anterior and posterior facial height Increase in FMA
Dental	Distal tipping of maxillary molar Mesial movement of mandibular molars Maxillary incisors palatally tipped Overjet and overbite reduction due to proclination of mandibular incisors	Intrusion and distal movement of maxillary molar Extrusion and mesial movement of mandibular molars Maxillary incisors retruded, extruded and retroclined Proclination of mandibular incisors minimized
Soft tissue	Increased nasolabial angle Retrusion of upper lip Lower lip moved forward Little forward movement of soft tissue Pog	Retrusion of upper lip Lower lip moved forward Significant movement of soft tissue Pog
Fem studies		
Effects	Dentally anchored FFRD	Skeletally anchored FFRD
Skeletal	Pterygoid plate exhibited posterior and superior displacement Increased maximum principal stress and von mises stress in the mandibular cortical bone and condyle Greatest displacement seen in the midsymphyseal and parasymphyseal regions.	Increased maximum principal stress and von mises stress in the mandibular cortical bone in the canine-premolar region and condyle
Dental	Maxillary dentition exhibited posterior and superior displacement Mandibular anterior teeth exhibited increased von mises stress.	Minimum stress exhibited in the mandibular anterior region
Soft tissue	-	-

Table 1

Conclusion

The Forsus Fatigue Resistance Device has been mainly used in adolescent non-compliant individuals who have passed the maximum pubertal growth. Both dentally anchored and skeletally anchored Forsus appliance has found to correct the skeletal class II malocclusion and improve the facial profile. In the present review, Pancherz analysis of various studies revealed that the dentally anchored forsus appliance contributed only 30% of skeletal correction and 70% dental correction. On contrary, skeletally anchored forsus appliance produced 70% skeletal correction and 30% dental correction. Further longitudinal studies with control group can substantiate the effects of skeletally anchored FFRD.

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